Louisiana Transportation Research Center

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Reliable Early Opening Strength for Concrete Pavements and Patch Work

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16. Abstract

The requirements for opening concrete pavement repairs to traffic vary greatly around the country. The reasons states and their transportation departments specify these different requirements includes traffic opening requirements, environmental conditions, and locally available materials, among other things.

This project reviewed the practices and requirements for early-opening-to-traffic concrete used by other state DOTs. The transportation agency has a need to specify the most efficient and effective early opening strengths and would benefit from understanding the latest thinking and practices adopted by similar agencies. Knowing the best approach to take can lead to dependable concrete, increased use of travel lanes, and a reduced cost of the materials and construction methods.

A comprehensive literature review of state specifications and rehabilitation policy was completed. Current and former research on the use of high early strength concrete in pavement rehabilitation was reviewed as well as various material and equipment requirements specified by states in pavement rehabilitation. This report also reviewed responses from a recent National Concrete Consortium state survey which compiled responses on opening and rehabilitation criteria from states across the country.

The current Louisiana opening specification for full-depth corner patching, full-depth jointed concrete patching, partial-depth patches of jointed concrete pavement, and continuously reinforced concrete pavement is an opening strength of 3000 psi. The state of Louisiana also allows the use of the maturity method to determine concrete strength on a project by project basis, with the approval of the Chief Construction Engineer. The current specifications are based solely on compressive strength and are not necessarily based on the mechanics of materials.

The authors recommend changing the 3000 psi requirement for early opening to traffic to the SHRP-206 findings of 2000 psi. To gain the maximum benefit of early opening, the authors also recommend full adoption of the maturity method for estimating in-place strength.

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IMPLEMENTATION STATEMENT

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INTRODUCTION

The increasing need for pavement rehabilitation coupled with the increase in traffic demand has led many states and regional transportation departments to review their often outdated requirements for concrete pavement opening strengths. There is a need to complete projects more efficiently, opening to traffic sooner, while maintaining pavement integrity and longevity. Completion of this research will give the Department direction as to the future of early opening concrete in DOTD construction projects. Concrete rehabilitation is critical in the service life of Louisiana roads and this synthesis will give direction on the proper method for utilizing early opening concrete.

OBJECTIVE

The objective of this synthesis project was to study the requirements for early-opening-to-traffic concrete used by other state DOTs. This research looks to improve opening times, cost of concrete, and road conditions while keeping in mind the dependability and durability of the concrete.

SCOPE

To meet the objectives of this project, a review of the state-of-the-practice and state specifications was completed for state departments around the country. As well as a review of current and former state surveys and specification reviews for early-opening-to-traffic requirements was completed.

METHODOLOGY

State of the Practice

A state-of-the practice literature review was conducted utilizing available peer reviewed literature available from materials available on the Transportation Research Information Database (TRID).

National Concrete Consortium

The national concrete consortium, a pooled fund project with upwards of 26 participating states conducted a survey on state specific rehabilitation practices. This results of this effort will be described.

DISCUSSION OF RESULTS

State of the Practice Review

This section will detail past research work completed on requirements for early opening strength across the country. There is an extensive amount of work already completed in this area. A search on the Transportation Research Information Database (TRID) for "concrete opening strength" provided over 400 literary works published since the 1960s on topics related to opening strength [*1-2*].

An American Concrete Pavement Association publication from 1995 provided guidance on design and construction of full depth concrete repairs [*3*]. The Association also included recommendations on opening strength seen in Table 1 below. Many of these strengths are lower than what is required currently in Louisiana.

Table 1
Recommended opening to traffic strength

Slab Thickness	Strength for Opening to Traffic MPa (psi)			
	Repair Length [<3 m (<10 ft)]		Slab Replacements	
	Compressive[1]	3rd-Point Flexural	Compressive[1]	3rd-Point Flexural
150 (6.0)	20.7 (3000)	3.4 (490)	24.8 (3600)	3.7 (540)
175 (7.0)	16.5 (2400)	2.6 (370)	18.6 (2700)	2.8 (410)
200 (8.0)	14.8 (2150)	2.3 (340)	14.8 (2150)	2.3 (340)
225 (9.0)	13.8 (2000)	1.9 (275)	13.8 (2000)	2.1 (300)
+250 (+10.0)	13.8 (2000)	1.7 (250)	13.8 (2000)	2.1 (300)

1. It is difficult to correlate compressive strength (f'_{cr}) to low values for flexural strength (f_r). The relationship $f_r = 0.79 \cdot \sqrt[0.79]{f'_{cr}}$ was used to develop the compressive strengths for f_r from 2.1 to 3.1 MPa (300 to 450 psi). The relationship $f_r = 9 \cdot \sqrt{f'_{cr}}$ was used to develop the compressive strengths for $f_r > 3.1$ MPa (450 psi).

Corvetti and Khazanovich performed a detailed field and laboratory analysis of early-age strength gain Portland cement concrete in Wisconsin, as well as the effects concrete strength has on dowel bars. They found that, when using 1.25-in. dowel bars, the required strength of 3000 psi should be maintained to resist damage under heavy traffic loads. On the other hand, using 1.5-in. dowel bars and taking into account factors, such as slab thickness and subgrade strength, the allowable opening strengths could be lowered to 2300 psi and still have adequate protection from excessive dowel bar stresses [*4-5*].

In the early 2000s, FHWA completed the SHRP2 program containing both the SHRP C-373 (optimization of highway concrete technology) SHRP C-206 (early opening of full depth repairs) test sites project. This early opening of a full-depth repair study found that the

performance of patching was highly variable and a key factor in performance was the temperature differential of the repair. They also found that for shorter repairs (less than 12 ft.) the fatigue damage due to opening early is negligible, even when opening to traffic at strengths as low as 6.9 MPa (≈1000 psi). They ultimately concluded that the strengths for opening to traffic could be lowered; however, it may lead to random failures caused by heavy loads. The authors' recommendation is to follow the opening criteria set out in SHRP C-206, which is a compressive strength of 13.8 MPa, roughly 2000 psi [*6-7*].

A March 2005 study completed by researchers at the University of Florida found that a minimum required compressive strength of 1100 to 1600 psi may be adequate to open to traffic and that lowering the Florida DOT specification from 2200 psi to 1600 psi at 6 hours may be possible with further research [*8*]. The study focused on full slab replacements and found that the temperature differential in the slabs greatly affected the long-term durability.

An NCHRP study lists 16 states' opening criteria and their mixture proportioning guidelines as of 2000. The opening requirements range in compressive strength from 1200 to 3000 psi, flexural strength from 260 psi to 400 psi, and some states only require a specified amount of time to wait before opening to traffic. The report mentions that these are all acceptable ways to open to traffic [*9*].

National Concrete Consortium State Report Results

In 2017, the National Concrete Consortium issued a state survey on concrete pavement rehabilitation. They received responses from 29 state DOTs and the Illinois Tollway. The questions related to departments full and partial depth repair practices, including opening requirements, dowel bar verifications, and grinding [*10-11*].

Responses for early opening to traffic included requirements for compressive strength, flexural strength, minimum time requirements, and mandatory use of the maturity method to estimate concrete strength. The responses from this state survey are similar to the literature review conducted by the NCHRP study in 2000. There is a wide range of opening requirements and repair processes across the country. These vast differences in requirements can be attributed to local traffic demand, climate, and even economics.

Current Standards

The current Louisiana opening specification for full-depth corner patching, full-depth jointed concrete patching, partial-depth patches of jointed concrete pavement, and continuously reinforced concrete pavement is an opening strength of 3000 psi. The state of Louisiana also

allows the use of the maturity method to determine concrete strength on a project by project basis, with the approval of the chief construction engineer. The current specifications are based solely on compressive strength and are not necessarily based on the mechanics of materials [*12*].

The use of the maturity method to determine concrete strength can be a useful tool in rehabilitation of PCC for the Department. This technology will allow the Department to save man hours on site and in the lab through the reduction in compressive strength testing requirements and will give the department an accurate measurement of in-place strength for determining time to open to traffic.

CONCLUSIONS

The results of this synthesis study indicate that the Department requires a significantly higher compressive strength than needed for early opening of concrete pavement patching. Reducing the required strength for opening to traffic and utilizing the maturity method for concrete strength estimation will benefit the Department. The authors recommend changing the required compressive strength from 3000 psi to 2000 psi. These changes will increase the durability of the repair while saving person-hours, lane closure delays, and possibly material costs.

RECOMMENDATIONS

The authors recommend changing the 3000 psi requirement for early opening to traffic to the SHRP-206 findings of 2000 psi. To gain the maximum benefit of early opening, the authors also recommend full adoption of the maturity method for estimating in-place strength.

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

ASTM	American Society of Testing and Materials
DOT	department of transportation
DOTD	Louisiana Department of Transportation and Development
FHWA	Federal Highway Administration
ft.	feet
in.	inch(es)
LTRC	Louisiana Transportation Research Center
PCC	portland cement concrete
pcf	pounds per cubic foot
psi	pounds per square inch
QA	quality assurance
QC	quality control

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